

## ORIGINAL RESEARCH

# Dietary Habits and Risk of Kidney Function Decline in an Urban Population

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**Objective:** Explore the association between following a Dietary Approaches to Stop Hypertension (DASH)-accordant diet and kidney end points among urban adults.

**Design:** Prospective cohort study.

**Setting:** Healthy Aging in Neighborhoods of Diversity across the Life Span study.

**Subjects:** A total of 1,534 urban dwelling participants of the Healthy Aging in Neighborhoods of Diversity across the Life Span study with a baseline estimated glomerular filtration rate (eGFR)  $\geq 60$  mL/minute/1.73 m<sup>2</sup>.

**Intervention:** DASH diet accordance determined via a score based on nine target nutrients.

**Main Outcome Measure:** Rapid kidney function decline (eGFR decline  $>3$  mL/minute/1.73 m<sup>2</sup> per year), incident chronic kidney disease (CKD) (follow-up eGFR  $<60$  mL/minute/1.73 m<sup>2</sup>), and eGFR decline  $>25\%$ .

**Results:** Participants' mean age was 48 years, and 59% were African-American. Median DASH score was 1.5 (range, 0-8). Over a median of 5 years, 13.4% experienced rapid eGFR decline, including 15.2% among participants not following a DASH-accordant diet (score  $\leq 1$ ) and 12.0% with higher accordance (score  $>1$ ) ( $P = .08$ ). Outcomes varied by hypertension status. In multinomial logistic regression models, following adjustment for sociodemographic and clinical factors, including total energy intake, low DASH diet accordance was associated with rapid eGFR decline among participants with hypertension (risk ratio, 1.68; 95% confidence interval: 1.17-2.42) but not among those without hypertension (risk ratio, 0.83; 95% confidence interval: 0.56-1.24;  $P$  interaction .001). There was no statistically significant association between DASH diet accordance and incident CKD or eGFR decline  $>25\%$ . Results were similar when DASH diet accordance was analyzed in tertiles.

**Conclusions:** Among urban adults, low accordance to a DASH-type diet was not associated with incident CKD, but was associated with higher risk of rapid eGFR decline among those with hypertension, yet not among those without hypertension. Further study of dietary patterns as a potential target for improving kidney outcomes among high-risk populations is warranted.

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## Introduction

IN THE PAST several decades, dietary patterns, one of the most modifiable lifestyle/behavioral factors, have been linked to risk for several chronic diseases.<sup>1</sup> Diets rich in vegetables, fruits, and soy while low in fats and meats have been concluded as healthy dietary patterns<sup>2</sup> and have shown protective associations with morbidity and mortality.<sup>3,4</sup>

The Dietary Approaches to Stop Hypertension (DASH) dietary pattern features high intake of vegetables, fruits, and low-fat dairy products with reduced total and saturated fat, cholesterol, and sugar-sweetened products.<sup>5</sup> It has been shown to lower blood pressure in prehypertensive and hypertensive adults.<sup>6</sup> A DASH-like diet has also been associated with lower risks of cardiovascular and cerebrovascular disease in observational studies.<sup>7</sup> Among kidney outcomes examined, accordance to a DASH-like diet was associated with slower estimated glomerular filtration rate (eGFR) decline among older white women with preserved kidney function.<sup>8</sup> Higher diet quality (based on Dietary Guidelines for Americans score) was associated

with both lower odds of incident chronic kidney disease (CKD) and eGFR decline.<sup>9</sup> In addition, an intervention study found that a dietary pattern rich in fruits and vegetables, similar to the DASH diet, attenuated markers of kidney injury among persons with hypertensive nephropathy.<sup>10</sup> However, the association of the DASH dietary pattern with kidney end points has not been examined among urban populations, where DASH diet accordance may be quite low.<sup>11</sup> Understanding the relationship between dietary patterns and kidney function decline could inform behavioral interventions targeting populations at high risk for CKD.

In this study, we investigated the association between patient-reported accordance to the DASH diet and rapid kidney function decline, incident CKD, and eGFR decline  $\geq 25\%$  among a racially and socioeconomically diverse, middle-aged, urban population.

## Subjects and Methods

### Study Design and Population

We examined longitudinal data from the National Institute on Aging, Healthy Aging in Neighborhoods of Diversity across the Life Span (HANDLS) study—a population-based cohort study. Participants were community-dwelling African-Americans and whites age 30–64 years at enrollment, drawn from 13 neighborhoods, each of which composed of contiguous US census tracts in Baltimore City, Maryland. Household enrollment was from 2004 to 2008. Participants were followed until death or the end of their follow-up visit when they were censored. The median follow-up for censored participants was 5 years (range, 1–8 years). Follow-up measures were performed from July 2009 to July 2013. Each participant provided informed consent. The National Institute of Environmental Health Sciences, National Institutes of Health, approved the study protocol.<sup>12</sup>

The total HANDLS study population was 3,720. We restricted our sample to participants who underwent baseline serum creatinine ( $n = 2,744$ ), baseline dietary intake measurements ( $n = 2,058$ ), and had an eGFR  $\geq 60$  mL/minute per  $1.73 \text{ m}^2$  at baseline ( $n = 1,940$ ). We further excluded those who survived but did not undergo a follow-up serum creatinine measurement (remaining  $n = 1,534$ ). Compared to the excluded individuals, our study sample was comparable in age, race, and poverty status, but was less likely to be male (42.0 vs. 47.7%,  $P = .001$ ).

### Measurements

#### Exposure

Participants' nonprescribed accordance to a DASH-like diet was determined using 24-hour self-reported food intake information gathered using the validated US Department of Agriculture's Automated Multiple Pass Method, versions 2.3–2.6, a computerized methodology,

on 2 days separated by 7–10 days.<sup>13</sup> This method was supplemented by measurement aids (e.g., measuring cups, spoons, etc.) to assist in estimating accurate quantities of foods and beverages. Both dietary recalls were administered in-person by trained interviewers. The dietary recalls were coded using Survey Net, matching foods consumed with codes in the Food and Nutrient Database for Dietary Studies, version 3. Energy and selected nutrient intakes were calculated for each recall day.<sup>14</sup> There were no significant differences in energy or nutrient intakes between the first and second recall days. The recalls represented both weekend and weekday consumption patterns, and no differences existed between energy and nutrient intakes by day of the week.

For this study, the mean nutrient values were used to assess DASH diet accordance as per the patient-reported DASH diet score developed by Mellen et al.<sup>15</sup> among participants of the National Health and Nutrition Examination Survey 1988–1994 and 1999–2004 periods who self-reported hypertension. Mellen et al identified DASH goals for eight target nutrients (total fat, saturated fat, protein, fiber, cholesterol, calcium, magnesium, and potassium). Although dietary sodium was held constant in the original DASH study,<sup>16</sup> sodium was included among the target nutrients. Nutrient goals were then indexed to total energy intake (with the exception of macronutrients), and the DASH score was generated by the sum of all nutrient targets met (maximum score, 9). Individuals with intake meeting a goal intermediate between the DASH goal and the nutrient content of the DASH control diet were given a score of 0.5 for that nutrient. Individuals meeting approximately half of the DASH targets (DASH score  $\geq 4.5$ ) were considered DASH accordant.<sup>15</sup>

### Outcomes

Our primary outcomes of interest were rapid kidney function decline, incident CKD, and eGFR decline  $\geq 25\%$ . Kidney end points were determined by eGFR calculated from serum creatinine using the CKD Epidemiology Collaboration creatinine-based equation.<sup>17</sup> For 9% of participants, creatinine was measured once at baseline and once at follow-up at the National Institute on Aging Clinical Research Branch Core Laboratory using a modified kinetic Jaffe method (CREA method, Dade Dimension X-Pand Clinical Chemistry System, Siemens Healthcare Diagnostics Inc., Newark, DE) and was measured for the remainder of participants at Quest Diagnostics, Inc. by isotope dilution mass spectrometry (Olympus America Inc., Melville, NY) and standardized to the reference laboratory at the Cleveland Clinic. Rapid kidney function decline was defined as a decrease in eGFR  $> 3$  mL/minute/ $1.73 \text{ m}^2$  per year during follow-up.<sup>18</sup> Incident CKD was defined as follow-up eGFR below 60 mL/minute per  $1.73 \text{ m}^2$ .<sup>19</sup> Estimated GFR decline  $\geq 25\%$  from baseline was also examined.<sup>19</sup>

### Covariates

Race was self-reported (African-American or white) during the initial household survey, where additional socio-demographic data including age, sex, level of educational attainment, report of a regular source of health care, health insurance coverage, and poverty status were also assessed. Poverty status was defined as a self-reported annual household income below 125% of the 2004 Department of Health and Human Services poverty guideline (family of 4 earning <\$23,562).<sup>20</sup> Tobacco use was defined as participants' self-report of smoking status. Height and weight were measured and used to calculate body mass index. A mobile research vehicle was the site of health care provider ascertained medical history and physical examination. Fasting venous blood specimen were also collected on the mobile research vehicle and analyzed at the NIA Clinical Research Branch Core Laboratory (Baltimore, MD) and Quest Diagnostics, Inc. (Baltimore, MD and Chantilly, VA).

Each participant underwent sitting and standing blood pressure measurements on each arm using the brachial artery auscultation method with an inflatable cuff of appropriate size. Seated measurements were made after 5 minutes of rest in a seated position, with feet flat on the floor and legs uncrossed. Standing measurements were made after the participant had been standing for at least 2 minutes. Hypertension was defined as an average of seated and standing systolic blood pressure  $\geq 140$  mm Hg, an average of seated and standing diastolic blood pressure  $\geq 90$  mm Hg,<sup>21</sup> a history of blood pressure medication use, or a self-report of hypertension. Diabetes mellitus was defined as a fasting plasma glucose concentration of  $\geq 126$  mg/dL (7.0 mmol/L) or self-report of diabetes.

### Statistical Analysis

Due to the low overall DASH diet adherence in the HANDLS study<sup>11</sup> and nonnormal distribution of DASH scores, we dichotomized participants into two groups around a score of 1.0, which was the 25th percentile for adherence. Thus, DASH scores  $\leq 1$  were considered low DASH adherence and those  $> 1$ , higher DASH adherence. Participant characteristics stratified by DASH diet adherence were compared using  $\chi^2$  tests or Fisher's exact tests for categorical variables and analysis of variance for continuous variables. Descriptive statistics and  $\chi^2$  square tests were used to compare the unadjusted occurrence of rapid kidney function decline, the unadjusted occurrence of incident CKD, and the unadjusted occurrence of eGFR decline  $\geq 25\%$ , separately, by DASH diet adherence. Multinomial logistic regression was performed to evaluate the odds of rapid eGFR decline, incident CKD, and eGFR decline  $\geq 25\%$ , separately, across DASH adherence groups that were conditional on the competing outcome of death. Multinomial logistic regression was used to account for the potential survival bias associated

with repeat assessment of biomarkers over time.<sup>22</sup> Given previous reports documenting that dietary patterns vary by race<sup>23</sup> and socioeconomic status<sup>11</sup> and given that hypertension and diabetes are both diet-sensitive chronic conditions, we analyzed each of these factors as potential effect modifiers. We tested the interaction of each potential effect modifier, separately, with DASH diet adherence. Potential confounders considered were those associated with dietary patterns and/or kidney function decline in previous studies, including sociodemographic characteristics (age, race, sex, poverty status, and education level), comorbid conditions (hypertension, diabetes, and systolic blood pressure), and health behaviors (tobacco use and total energy intake). For outcomes with low event rates, we examined a parsimonious set of variables (age, sex, race, and poverty status). To further explore the relationship between DASH diet adherence and kidney function decline, we (1) descriptively compared nutrient intakes between participants with and without rapid eGFR decline and (2) used multivariable logistic regression to test the association between individual DASH nutrient scores (range, 0–1) and kidney outcomes (all individual DASH nutrients were included in the model, adjusted for each other).

We performed three sensitivity analyses. First, we repeated our primary models with DASH diet adherence stratified by tertiles. Second, we restricted our sample to participants with available urinary albumin and creatinine data ( $n = 983$ ), replicated our analysis for the rapid eGFR decline models, and further adjusted for urine albumin-to-creatinine ratio (ACR). Third, for kidney outcomes, we restricted to participants with creatinine measured at the same laboratory at baseline and follow-up ( $n = 1,408$ ).

In all analyses, the possibility of confounding by US census tract was controlled with fixed effects modeling, clustered on neighborhood. Statistical analyses were performed using Stata software, version 13 (StataCorp, College Station, TX). A two-sided  $P < .05$  was used as the level of significance for all tests.

## Results

### Participant Characteristics and DASH Diet Adherence

Among 1,534 participants, DASH diet adherence was minimal, with a median score of 1.5 and interquartile range of 1 to 2.5. Only 5.7% of participants reported dietary patterns consistent with the diet (DASH score  $\geq 4.5$ ), as in our previous report.<sup>11</sup> Examination of participant characteristics comparing low and higher DASH adherence groups revealed that male sex, African-American race, poverty, fewer years of education, tobacco use, and higher level of total energy intake were each more prevalent among the low DASH adherence group than the higher adherence group ( $P < .05$  for all). Median baseline eGFR was comparable between the groups (Table 1).

**Table 1.** Participant Characteristics by Dietary Approaches to Stop Hypertension (DASH) Diet\* Accordance (N = 1,534)

Participant Characteristics	N	DASH Diet Accordance		P Value
		Higher (Accordance Scores 1.5-8.0), n = 886 (58%)	Low (Accordance Scores 0-1.0), n = 648 (42%)	
African-American race	1,534	481 (54.3)	419 (64.7)	<.001
Age, years, mean (SD)	1,534	47.8 (9.4)	47.6 (8.6)	.678
Male sex	1,534	347 (39.2)	297 (45.8)	.009
Education, years, mean (SD)	1,532	12.9 (3.3)	12.3 (2.9)	<.001
Regular source of health care	1,534	596 (67.3)	406 (62.7)	.061
Insurance	1,534	622 (70.2)	434 (67.0)	.178
Poverty	1,534	338 (38.2)	291 (44.9)	.008
Tobacco use	1,462			<.001
Current	675	353 (41.7)	322 (52.3)	
Former	304	181 (21.4)	123 (20.0)	
None	483	312 (36.9)	171 (27.8)	
BMI, kg/m <sup>2</sup> , mean (SD)	1,532	29.8 (7.8)	29.7 (7.6)	.753
eGFR ml/min/1.73 m <sup>2</sup> †	1,534	95 (82-108)	96 (83-108)	.579
Obesity‡	1,534	376 (42.4)	266 (41.1)	.601
Systolic BP (mm/Hg)	1,523	119 (19)	120 (19)	.151
Hypertension	1,529	380 (43.0)	272 (42.1)	.753
Diabetes	1,529	138 (15.6)	100 (15.5)	.955
Total energy intake, kilocalories/d, mean (SD)	1,533	1,863 (898)	2,233 (972)	<.001

BMI, body mass index; BP, blood pressure; eGFR, estimated glomerular filtration rate; SD, standard deviation.

\*Individuals meeting the DASH target for a nutrient received a score of 1, while those who achieved the intermediate target for a nutrient received a score of 0.5 for that nutrient, for a total possible score of 9.

†Median (interquartile range) presented.

‡Obesity was defined as BMI  $\geq 30$  kg/m<sup>2</sup>.

## DASH Diet Accordance and Rapid eGFR Decline

A total of 1,443 participants survived and completed follow-up creatinine measures (91 died during follow-up). Among the survivors, 193 (13.4%) experienced rapid eGFR decline over 6,673 person years, including 12.0% of the higher DASH and 15.2% of the low DASH accordance groups. Compared to higher DASH accordance, low DASH accordance was not associated with a greater risk of rapid eGFR decline (unadjusted risk ratio [RR], 1.31; 95% confidence interval [CI]: 0.99-1.78; adjusted RR, 1.22; 95% CI: 0.92-1.63 [adjusted for age, sex, race, poverty status, tobacco use, education level, hypertension, diabetes, systolic blood pressure, and total energy intake]). Effect modification by hypertension status was noted ( $P$  interaction .008), and therefore, we stratified our subsequent models by hypertension status (Table 2). The unadjusted association between DASH diet accordance and rapid eGFR decline was statistically significant among hypertensive participants yet not among nonhypertensives (Fig. 1). These associations persisted following adjustment for age, sex, race, poverty, smoking status, education, diabetes, systolic blood pressure, and total energy intake (Table 3).

Nutrient intakes differed between participants with and without rapid eGFR decline (Table 4). The rapid eGFR decline group had lower magnesium and calcium intake,

and protein comprised a lower proportion of their diets than those without rapid eGFR decline ( $P < .05$  for all). Potassium intake was also lower among the rapid eGFR decline group ( $P = .10$ ). Multivariable logistic regression revealed, among all participants, that meeting the DASH diet protein target of  $\geq 18\%$  of total energy intake was associated with lesser odds of rapid eGFR decline (OR, 0.64; 95% CI: 0.41-0.99). Among hypertensive participants, meeting the protein target and meeting the sodium target were independently associated with lesser odds of rapid kidney function decline (protein OR, 0.53; 95% CI: 0.29-0.99; sodium OR, 0.37; 95% CI: 0.15-0.89). No significant association between individual DASH nutrient targets and rapid eGFR decline was identified among nonhypertensive participants.

## DASH Diet Accordance and Incident CKD or eGFR Decline $\geq 25\%$

Fully, 38 patients (2.6%) developed incident CKD (eGFR  $< 60$ ) and 65 patients (4.5%) experienced eGFR decline  $\geq 25\%$  during follow-up. After adjustment for age, sex, race, and poverty status, low DASH accordance was not associated with risk of either outcome (Table 5). No effect modification was identified.

## Sensitivity Analyses

Analyses categorizing DASH diet accordance into tertiles (tertile 1: DASH score 0-1,  $n = 648$ ; tertile 2:

**Table 2.** Participant Characteristics by Hypertension Status and Dietary Approaches to Stop Hypertension (DASH)\* Diet Accordance (N = 1,529)

Participant Characteristics	Non-HTN, N = 877 (57%)				HTN, N = 652 (43%)			
	All	Higher DASH	Low DASH	P Value	All	Higher DASH	Low DASH	P Value
African-American race	480 (54.7)	245 (48.7)	235 (62.8)	<.001	416 (63.8)	234 (61.6)	182 (66.9)	.162
Age, years, mean (SD)	45.0 (8.6)	45.1 (8.9)	44.9 (8.1)	.721	51.3 (8.4)	51.3 (8.9)	51.3 (7.8)	.965
Male sex	388 (44.2)	210 (41.8)	178 (47.6)	.805	255 (39.1)	137 (36.1)	11,888 (43.4)	.059
Education, years, mean (SD)	12.9 (3.2)	13.3 (3.4)	12.3 (3.0)	<.001	12.2 (3.0)	12.3 (3.1)	12.2 (2.8)	.650
Regular source of health care	508 (57.9)	294 (58.5)	214 (57.2)	.715	492 (75.5)	300 (79.0)	192 (70.6)	.014
Insurance	569 (64.9)	333 (66.2)	236 (63.1)	.341	482 (3.9)	286 (75.3)	196 (72.1)	.358
Poverty	335 (38.2)	179 (35.6)	156 (41.7)	.065	291 (44.6)	157 (41.3)	134 (49.3)	.044
Tobacco use				.020				.003
Current	417 (50.0)	218 (45.8)	199 (55.6)		258 (41.1)	135 (36.5)	123 (47.7)	
Former	139 (16.7)	85 (17.9)	54 (15.1)		165 (26.3)	96 (26.0)	69 (26.7)	
None	278 (33.3)	173 (36.3)	105 (29.3)		205 (32.6)	139 (37.6)	66 (25.6)	
BMI, kg/m <sup>2</sup> , mean (SD)	27.9 (6.7)	27.8 (6.7)	27.9 (6.7)	.830	32.3 (8.2)	32.5 (8.3)	32.1 (8.2)	.598
eGFR ml/min/1.73 m <sup>2</sup> †	97 (84-110)	97 (83-110)	97 (86-109)	.583	93 (80-104)	93 (80-103)	92 (81-105)	.880
Obesity‡	278 (31.7)	158 (31.4)	120 (32.1)	.832	361 (55.4)	216 (56.8)	145 (53.3)	.371
Systolic BP (mm/Hg)	112 (14)	112 (14)	112 (14)	.641	130 (20)	128 (21)	131 (18)	.053
Diabetes	57 (6.5)	34 (6.8)	23 (6.2)	.735	181 (27.8)	104 (27.4)	77 (28.3)	.807
Total energy intake, kilocalories/d, mean (SD)	2,103 (957)	1,964 (908)	2,289 (991)	<.001	1,909 (924)	1,727 (866)	2,162 (945)	<.001

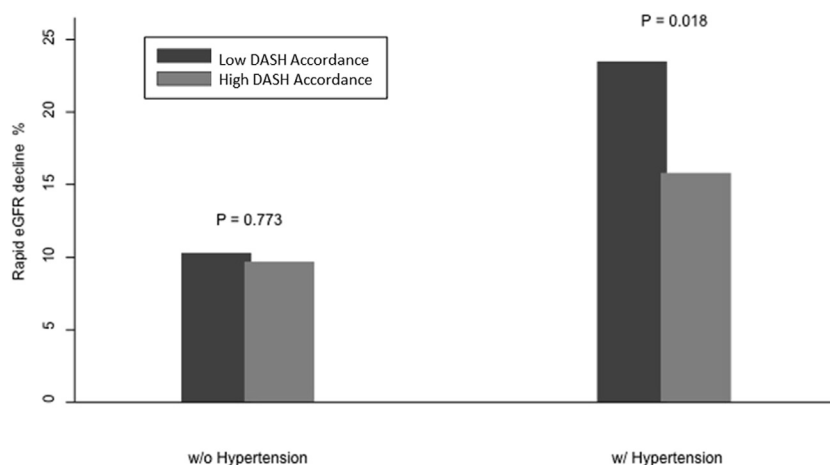
BMI, body mass index; BP, blood pressure; eGFR, estimated glomerular filtration rate; HTN, hypertension; SD, standard deviation.

\*Individuals meeting the DASH target for a nutrient received a score of 1, while those who achieved the intermediate target for a nutrient received a score of 0.5 for that nutrient, for a total possible score of 9.

†Median (interquartile range) was presented instead of mean (SD).

‡Obesity was defined as BMI  $\geq 30$  kg/m<sup>2</sup>.





**Figure 1.** Rapid eGFR decline by hypertension status and Dietary Approaches to Stop Hypertension (DASH) diet adherence. Rapid eGFR decline defined as eGFR decrease  $>3$  mL/minute per  $1.73$  m<sup>2</sup> per year during follow-up. eGFR, estimated glomerular filtration rate.

DASH score 1.5–2,  $n = 445$ ; and tertile 3: DASH score 2.5–7.5,  $n = 441$ ) yielded similar results to our primary models. There was no statistically significant association between DASH diet adherence and rapid eGFR decline or incident CKD. Effect modification by hypertension status was noted for rapid eGFR decline ( $P$  interaction .001). Among hypertensive participants, the adjusted RR comparing DASH tertile 1 to 3 was 1.49 (95% CI: 0.98–2.25); while among nonhypertensive participants, the adjusted RR was 0.89 (95% CI: 0.49–1.64).

A total of 983 (64%) participants had available urinary ACR data. Compared to the primary analysis cohort, this subset was comparable in age and gender, yet had fewer African-Americans (56% vs. 64%) and less poverty (31% vs. 59%). Here, there was no association between low DASH adherence and rapid eGFR decline (adjusted RR, 0.86; 95% CI: 0.73–1.00, following adjustment for

age, sex, race, poverty status, tobacco use, education level, hypertension, and diabetes). After further adjustment for baseline ACR, results were unchanged (adjusted RR, 0.84; 95% CI: 0.71–1.00). Stratified analyses by hypertension status, and adjusted for age, sex, race, poverty status, tobacco use, education, and diabetes status, yielded an adjusted RR (comparing low DASH adherence to higher adherence) of 1.06, 95% CI: 0.71–1.57 among hypertensive participants; and an adjusted RR 0.65, 95% CI 0.50–0.84 among nonhypertensive participants. Further adjustment for baseline ACR again did not change the magnitude or direction of the associations. Among participants who had follow-up creatinine measured at the same laboratory as their baseline creatinine ( $n = 1,408$ ), results were similar to our primary analyses, both before and after stratification by hypertension (data not shown).

**Table 3.** Multinomial Logistic Regression Analyses for Associations Between Low Dietary Approaches to Stop Hypertension (DASH)\* Accordance (Compared to Higher Accordance) and Rapid eGFR Decline† ( $N = 1,529$ )

Model	Variables Included	Non-HTN, $N = 877$ , $N$ Events = 93	HTN, $N = 652$ , $N$ Events = 100	$P$ interaction
		Risk Ratio (95% Confidence Interval)	Risk Ratio (95% Confidence Interval)	Between HTN and DASH Accordance Groups
1	Low versus higher DASH adherence	0.97 (0.66, 1.44)	1.80 (1.33, 2.44)	.001
2	+ Age, sex, race	0.94 (0.61, 1.44)	1.80 (1.33, 2.45)	.001
3	+ Poverty status, tobacco use, education level	0.87 (0.60, 1.25)	1.74 (1.22, 2.47)	.001
4	+ Diabetes	0.87 (0.60, 1.26)	1.71 (1.19, 2.44)	.001
5	+ Systolic BP	0.89 (0.61, 1.29)	1.68 (1.17, 2.42)	.001
6	+ Total energy intake	0.83 (0.56, 1.24)	1.68 (1.17, 2.42)	.001

BP, blood pressure; eGFR, estimated glomerular filtration rate; HTN, hypertension.

\*Individuals meeting the DASH target for a nutrient received a score of 1, while those who achieved the intermediate target for a nutrient received a score of 0.5 for that nutrient, for a total possible adherence score of 9. Persons with adherence scores falling between 0 and 1.0 were defined as low DASH adherence, while those with higher DASH adherence had scores between 1.5 and 8.0.

†Rapid eGFR decline defined as eGFR decrease  $>3$  mL/minute per  $1.73$  m<sup>2</sup> per year during follow-up.

**Table 4.** Dietary Approaches to Stop Hypertension (DASH)\* Diet Accordant Nutrient Intakes by eGFR Decline Status at Follow-Up† (N = 1,443)

DASH Nutrients	DASH Target	eGFR Decline $\leq 3$ mL/min per 1.73 m <sup>2</sup> per Year, N = 1,250	eGFR Decline $> 3$ mL/min per 1.73 m <sup>2</sup> per Year, N = 193	P Value
Saturated fat, % energy	$\leq 6$	12	11	.43
Total fat, % energy	$\leq 27$	35	35	.55
Protein, % energy	$\geq 18$	16	15	.01
Cholesterol, mg/1,000 kcal	$\leq 71.4$	163	152	.11
Fiber, g/1,000 kcal	$\geq 14.8$	6.4	5.9	.07
Magnesium, mg/1,000 kcal	$\geq 238$	126	119	.03
Calcium, mg/1,000 kcal	$\geq 590$	380	350	.04
Potassium, mg/1,000 kcal	$\geq 2,238$	1,167	1,119	.10
Sodium, mg/1,000 kcal	$\leq 1,143$	1,589	1,579	.77
Total DASH score	9.0	1.8	1.6	.06
DASH, % adherent (total score $\geq 4.5$ )	—	5.9	4.6	.43

eGFR, estimated glomerular filtration rate.

\*Individuals meeting the DASH target for a nutrient received a score of 1, while those who achieved the intermediate target for a nutrient received a score of 0.5 for that nutrient, for a total possible accordance score of 9. Individuals with a total DASH score  $\geq 4.5$  are considered as DASH adherent.

†Rapid eGFR decline defined as eGFR decrease  $> 3$  mL/minute per 1.73 m<sup>2</sup> per year during follow-up.

## Discussion

Among this racially balanced urban sample of adults, we observed that low accordance to a DASH-like diet was not associated with incident CKD or eGFR decline  $\geq 25\%$  during 5 years of follow-up, but was associated with greater odds of rapid kidney function decline among individuals with hypertension. Among normotensive individuals, we found no association between DASH diet accordance and kidney function decline. Our findings persisted after adjustment for sociodemographic factors and did not vary by race, poverty status, or diabetes status.

Previous studies have documented an association between healthful dietary patterns and kidney outcomes, including the DASH diet.<sup>8</sup> Cross-sectional reports suggest accordance to the Mediterranean diet, which shares several characteristics with the DASH diet, is associated with lower prevalence of reduced eGFR among older<sup>24</sup> and middle-aged<sup>11</sup> populations. Greater diet quality, in general, has been associated with a lower prevalence of reduced kidney

function among older adults.<sup>25</sup> Our work extends that of previous studies by examining the relationship between DASH diet accordance and longitudinal kidney outcomes among a middle-aged, urban population with preserved eGFR at baseline.

If confirmed in other samples, a potential explanation for an association between DASH diet accordance and favorable kidney outcomes could relate to the low dietary acid load (DAL) of the DASH diet. DAL is determined by the difference between endogenously produced nonvolatile acid and absorbed alkali precursors and must be excreted by the kidney to maintain acid-base balance.<sup>26</sup> The estimated potential renal acid load of the DASH diet is  $-25.5$  mEq/day,<sup>27</sup> which is much lower than the 50–75 mEq/day observed in several general populations.<sup>28,29</sup> Mechanisms underlying the association of DAL and kidney injury may include tubular toxicity of elevated ammonium concentration and increased angiotensin II activity with succeeding acidification of the distal

**Table 5.** Multinomial Logistic Regression Analyses for Associations Between Dietary Approaches to Stop Hypertension (DASH) Diet\* Accordance and Incident Chronic Kidney Disease (CKD) or eGFR Decline  $\geq 25\%$ † (N = 1,534)

		Incident CKD (eGFR <60 at Follow-Up) <sup>†</sup>	eGFR Decline ≥25%
		N Events = 38	N Event = 65
Model	Variable Included	Risk Ratio (95% Confidence Interval)	
1	Low versus higher DASH accordance	1.52 (0.92, 2.52)	1.23 (0.75, 2.02)
2	+ Age, sex, race	1.49 (0.84, 2.63)	1.36 (0.78, 2.37)
3	+ Poverty status <sup>†</sup>	1.48 (0.84, 2.61)	1.30 (0.76, 2.23)

eGFR, estimated glomerular filtration rate.

\*Individuals meeting the DASH target for a nutrient received a score of 1, while those who achieved the intermediate target for a nutrient received a score of 0.5 for that nutrient, for a total possible accordance score of 9. Persons with accordance scores falling between 0 and 1.0 were defined as low DASH accordance, while those with higher DASH accordance had scores between 1.5 and 8.0.

†Incident CKD was defined as follow-up eGFR below 60 mL/minute per 1.73 m<sup>2</sup>.

nephron.<sup>30</sup> Several studies have documented potential kidney benefits of a diet low in DAL.<sup>23,31,32</sup> Additionally, the association we found solely among participants with hypertension may be explained by the beneficial effect of the DASH diet on vascular injury and endothelial dysfunction.<sup>33</sup>

In our study, most nutrients included in the DASH diet score were comparably consumed between participants who did and did not experience rapid eGFR decline, except for protein, magnesium, and calcium. Protein comprised a slightly lower percentage of daily nutrient intakes among participants with rapid eGFR decline as compared to those without; and overall and among hypertensive participants, meeting the DASH diet protein target was associated with lesser odds of rapid kidney function decline. Given the lack of clarity on the potential benefits and harms of protein intake for the preservation of kidney function,<sup>34</sup> future longitudinal studies are warranted that, in particular, examine the source of protein (animal vs. plant) in the context of overall healthful dietary patterns.

Significantly lower magnesium intakes were observed among individuals who experienced rapid eGFR decline, which is consistent with findings of associations between low serum magnesium<sup>35</sup> and low magnesium intake<sup>36</sup> with greater risk of incident CKD. A previous observational study also reported that higher serum magnesium was associated with less endothelial dysfunction, and separately, with higher eGFR, suggesting that magnesium may protect against endothelial damage.<sup>37</sup> This finding supports the hypothesis that the vasodilatory effects of micronutrients, like magnesium, might contribute to the beneficial effects of the DASH diet on endothelial function. Significantly lower calcium intake was reported among participants who developed rapid eGFR decline. Similar to magnesium, calcium has also been noted to have favorable effects on endothelial function.<sup>38</sup>

While sodium consumption was not significantly different between participants who did or did not experience rapid kidney function decline, meeting the DASH sodium target was independently associated with lesser odds of rapid eGFR decline among hypertensive participants. This finding suggests that reduced sodium intake, which is known to favorably influence blood pressure control, might have protective effects on eGFR decline. A recently published study among persons with CKD enrolled in the Chronic Renal Insufficiency Cohort found that higher urinary sodium excretion (a correlate of sodium intake) was associated with greater risk of CKD progression.<sup>39</sup> These results and ours argue that sodium intake may be an important contributor to outcomes among persons at high risk for eGFR decline.

Our study had limitations. First, we were missing complete data for some participants and, in particular, had fewer males in our study sample than in the full HANDLS cohort. We believe that our estimates may be conservative as the as-

sociation of low DASH diet accordance with rapid eGFR decline was slightly stronger among hypertensive males in our sample as compared to females ([Supplementary Table A](#)). Second, our results may have been influenced by the use of the DASH score by Mellen et al. Others have operationalized DASH diet accordance differently, and some clinical outcomes have been found to be differentially associated with these various indices.<sup>40,41</sup> Third, data on some important factors related to dietary intake and potentially to CKD, such as food additives,<sup>42</sup> nutritional supplements,<sup>43</sup> availability of healthful foods in neighborhood stores, and physical activity<sup>44</sup> were unavailable. Fourth, some level of error has been associated with the measurement of food consumption. The energy intake measurement we used has been reported to underreport energy intake for both normal weight (by less than 3%) and overweight (by 16%) subjects,<sup>13</sup> compared to the doubly labeled water technique, as we previously described.<sup>11</sup> Fifth, because of variability in serum creatinine measures, changes based on only two data points could be due to random variation.<sup>45</sup> Sixth, we lacked 24-hour urine collections to allow for direct analyses of DAL (estimated by net acid excretion) as a potential mediator of the association of dietary patterns with kidney outcomes. Future studies in this area are warranted.

Our findings could have important implications. The US Preventive Services Task Force has recommended behavioral counseling interventions in primary care settings to promote a healthful diet and physical activity for cardiovascular disease prevention in adults.<sup>46</sup> Toward diminishing the kidney disease burden in the United States, our study provides evidence of potential benefits of a DASH-like dietary pattern for CKD prevention among hypertensive patients.

In conclusion, DASH diet accordance was low among this middle-aged urban population. Low DASH diet accordance was not associated with incident CKD or eGFR decline  $\geq 25\%$ , but was associated with greater risk for rapid kidney function decline among hypertensive individuals, yet not among nonhypertensive individuals. The role of diet quality in determining risk for kidney disease is worthy of further investigation.

## Practical Application

Accordance to a DASH diet may be associated with lower risk of rapid kidney function decline among individuals with hypertension. This finding suggests that diet quality may play an important role in determining kidney outcomes among individuals with risk factors for CKD.

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## Supplementary Data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1053/j.jrn.2016.08.007>.

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**SUPPLEMENTARY TABLE A.** Selection bias assessment through sex-stratified analysis on association between DASH dietary accordanc<sup>£</sup> and rapid eGFR decline\* (N = 1534).

Model	Variables Included	Male (N = 644)	Female (N = 890)
		RR (95% CI)	RR (95% CI)
1	DASH Accordance	1.56 (0.97, 2.50)	1.22 (0.78, 1.92)
2	Model 1 + Age, Sex, Race	1.47 (0.88, 2.46)	1.22 (0.78, 1.89)
3	Model 2 + Poverty Status**, Tobacco Use, Education level	1.32 (0.76, 2.30)	1.20 (0.80, 1.79)
4	Model 3 + HTN	1.35 (0.79, 2.31)	1.21 (0.80, 1.82)
5	Model 3 + Diabetes <sup>ϕ</sup>	1.35 (0.80, 2.30)	1.19 (0.80, 1.79)
6	Model 5+ Systolic BP	1.42 (0.81, 2.49)	1.19 (0.78, 1.81)
7	Model 6 + Total Energy Intake	1.42 (0.81, 2.49)	1.10 (0.73, 1.65)
Among non-HTN (N = 877)			
1	DASH Accordance	1.29 (0.67, 2.48)	0.85 (0.37, 1.95)
2	Model 1 + Age, Sex, Race	1.15 (0.59, 2.24)	0.84 (0.34, 2.08)
3	Model 2 + Poverty Status**, Tobacco Use, Education level	1.05 (0.52, 2.16)	0.78 (0.34, 1.79)
4	Model 3 + Diabetes	1.07 (0.51, 2.22)	0.78 (0.34, 1.79)
5	Model 4+ Systolic BP	1.15 (0.54, 2.44)	0.78 (0.33, 1.80)
6	Model 5 + Total Energy Intake	1.08 (0.53, 2.23)	0.72 (0.31, 1.68)
Among HTN (N = 652)			
1	DASH Accordance	1.89 (0.94, 3.79)	1.77 (1.10, 2.83)
2	Model 1 + Age, Sex, Race	1.88 (0.93, 3.80)	1.77 (1.12, 2.79)
3	Model 2 + Poverty Status**, Tobacco Use, Education level	1.66 (0.76, 3.61)	1.77 (1.08, 2.91)
4	Model 3 + Diabetes	1.65 (0.76, 3.60)	1.72 (1.06, 2.80)
5	Model 4+ Systolic BP	1.69 (0.78, 3.67)	1.66 (1.00, 2.74)
6	Model 5 + Total Energy Intake	1.75 (0.79, 3.84)	1.57 (0.93, 2.66)

Abbreviations: HTN, hypertension; BP, blood pressure.

£ Individuals meeting the DASH target for a nutrient received a score of 1 while those who achieved the intermediate target for a nutrient received a score of 0.5 for that nutrient, for a total possible accordance score of 9.<sup>21,22</sup> People with accordance scores falling between 0-1.0 were defined as low DASH accordance, while people with higher DASH accordance had scores between 1.5 and 8.0.

\* Rapid eGFR decline defined as eGFR decrease > 3 mL/min per 1.73 m<sup>2</sup> per year during follow-up.

\*\* Poverty status defined as a self-reported annual household income below 125% of the 2004 Department of Health and Human Services poverty guideline (family of 4 earning <\$23,562).<sup>27</sup>

ζ Hypertension was defined as an average of seated and standing systolic blood pressure ≥ 140 mmHg, an average of seated and standing diastolic blood pressure ≥ 90 mmHg 27, a history of blood pressure medication use, or a self-report of hypertension.

ϕ Diabetes mellitus was defined as a fasting plasma glucose concentration of ≥126 mg/dl (7.0 mmol/l), or self-report of diabetes.